



DEPARTMENT OF EARTH AND
ENVIRONMENTAL SCIENCES
K.U. LEUVEN - BELGIUM



Understanding the performance of FLake over the African Great Lakes

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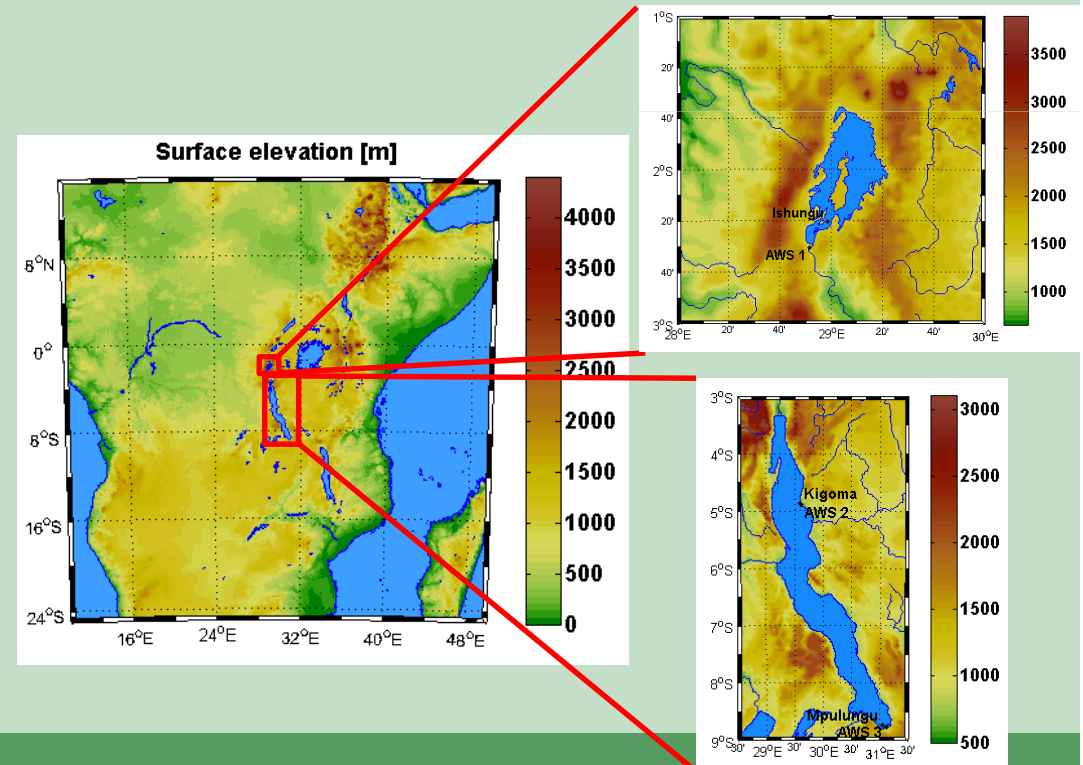
LakeMIP-Kivu

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Z. Subin, N. van Lipzig¹



Motivation & Objectives

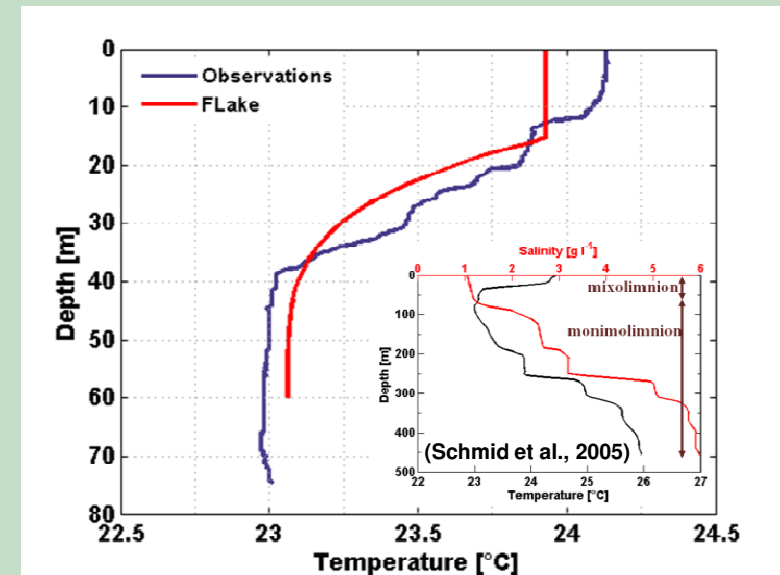
- large lakes have a significant impact on regional climate
- even though FLake has become a landmark for lake parameterisation in NWP and RCM's (e.g. Mironov et al., 2010; Martynov et al., 2011), it has never been tested for tropical conditions
- evaluate FLake performance over lake Kivu and lake Tanganyika and understand seasonal & spatial variability, also in contrast to other models
- consortium of biogeochemists and ecologists working on lake Kivu need reliable information on climate change impact on the lake's mixing regime





Method: FLake configuration

- FLake model (Mironov, 2008):
 - 1D, two-layer bulk model
 - mixed layer: uniform T
 - thermocline: self-similarity of T-z curve
- FLake standalone configuration:
 - artificial lake depth 60m
 - initialisation: climatological profile January
 - spin-up until convergence (9 – 30 yr)
 - no active sediments
 - wind velocity tuned cfr. AWS Kivu: + 1 m s⁻¹
 - *k* tuned cfr. obs: 0.32 m⁻¹



} AWS control



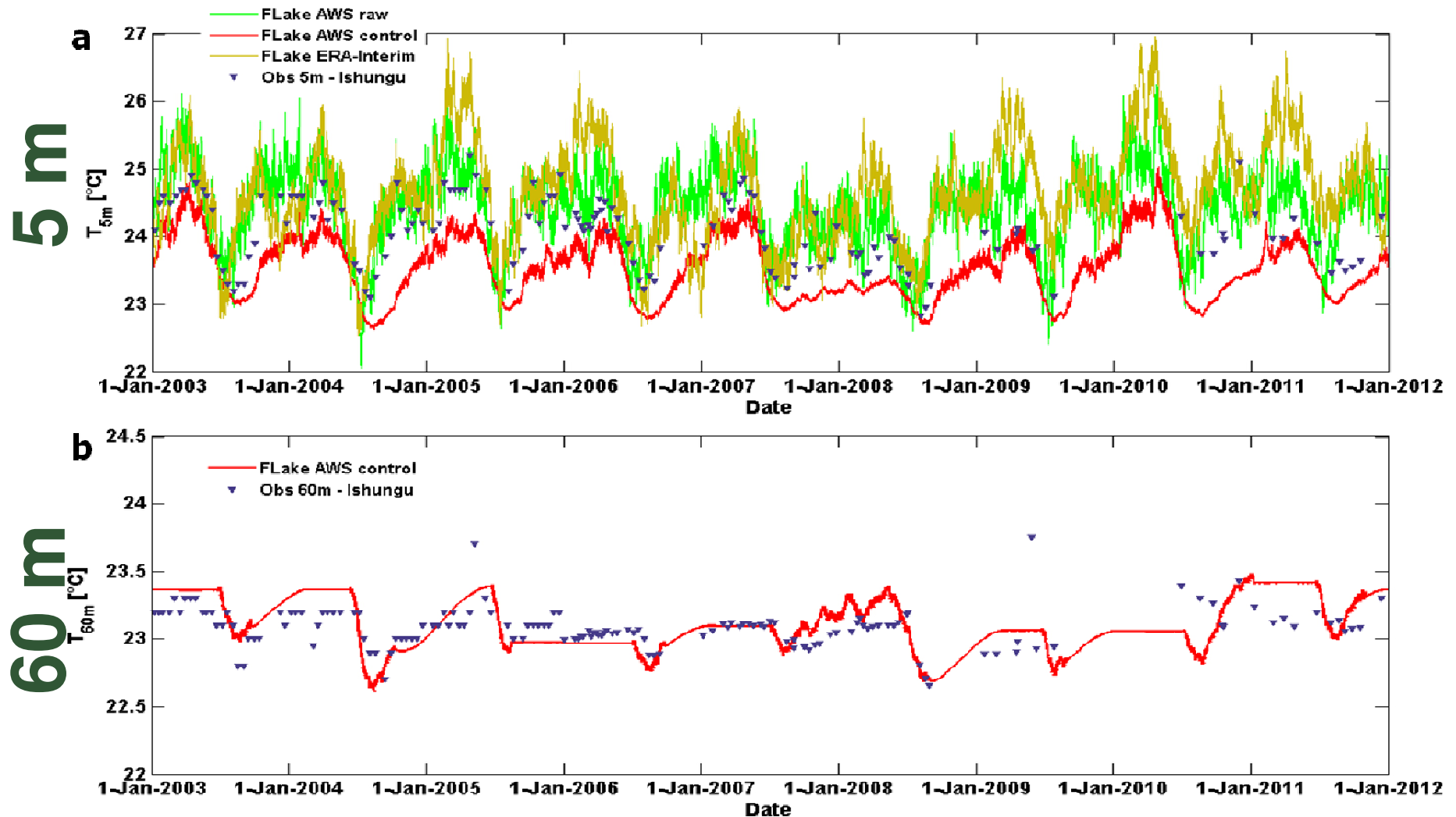
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Method: data correction





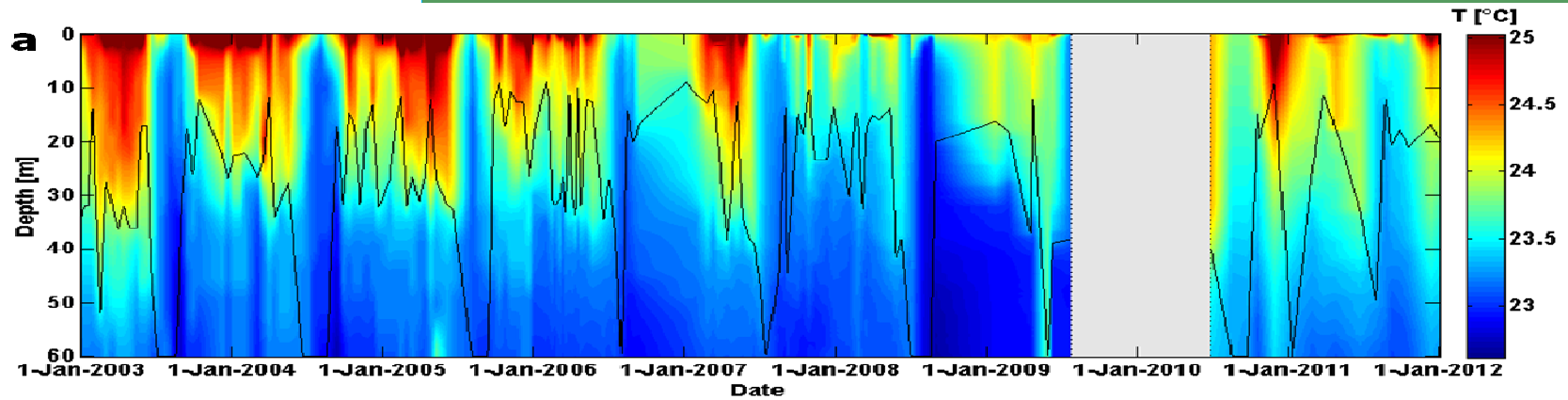
Results: Ishungu



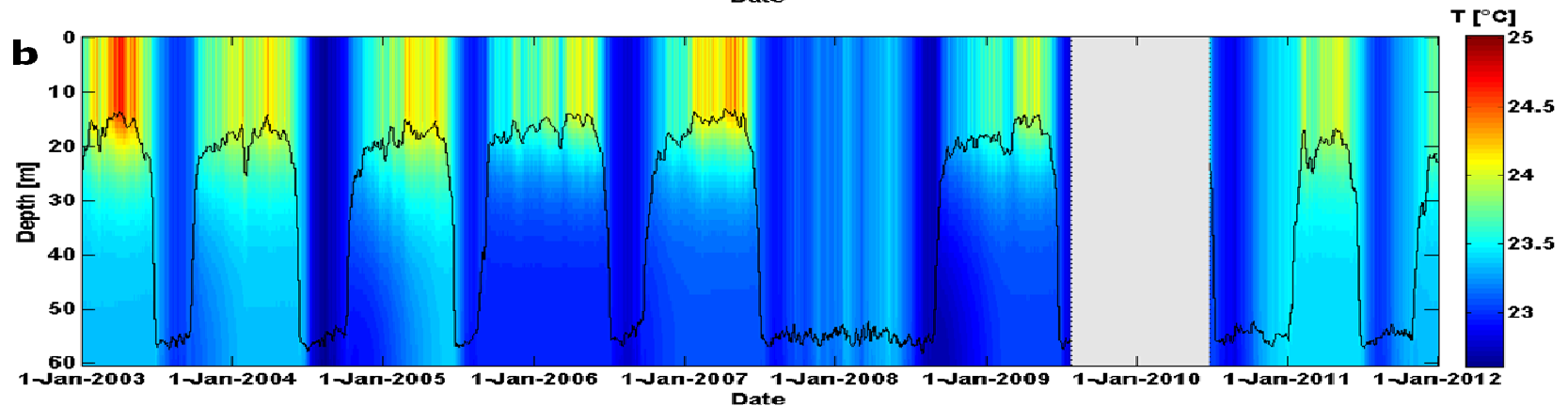


Results: Ishungu

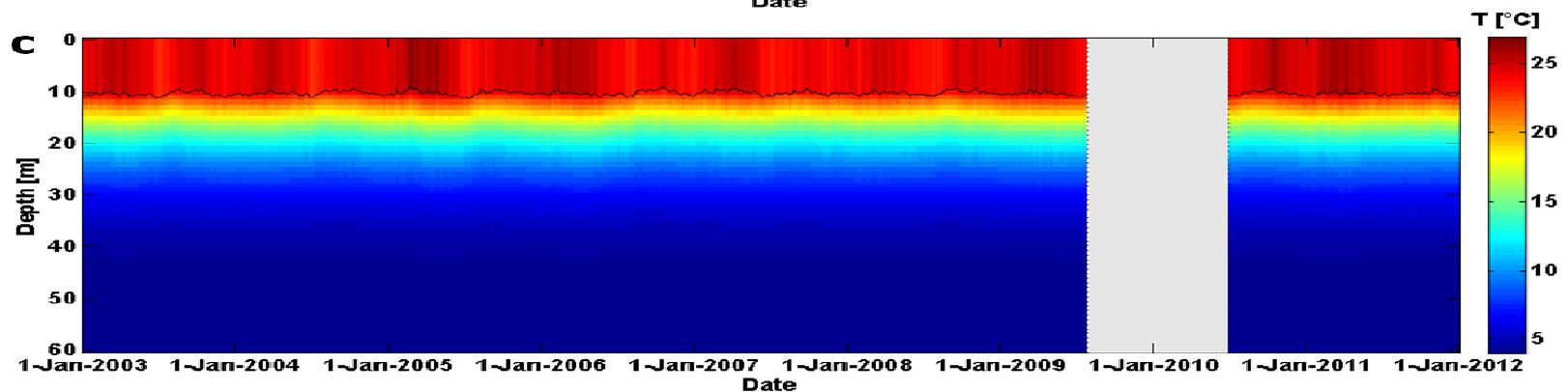
Obs



AWS



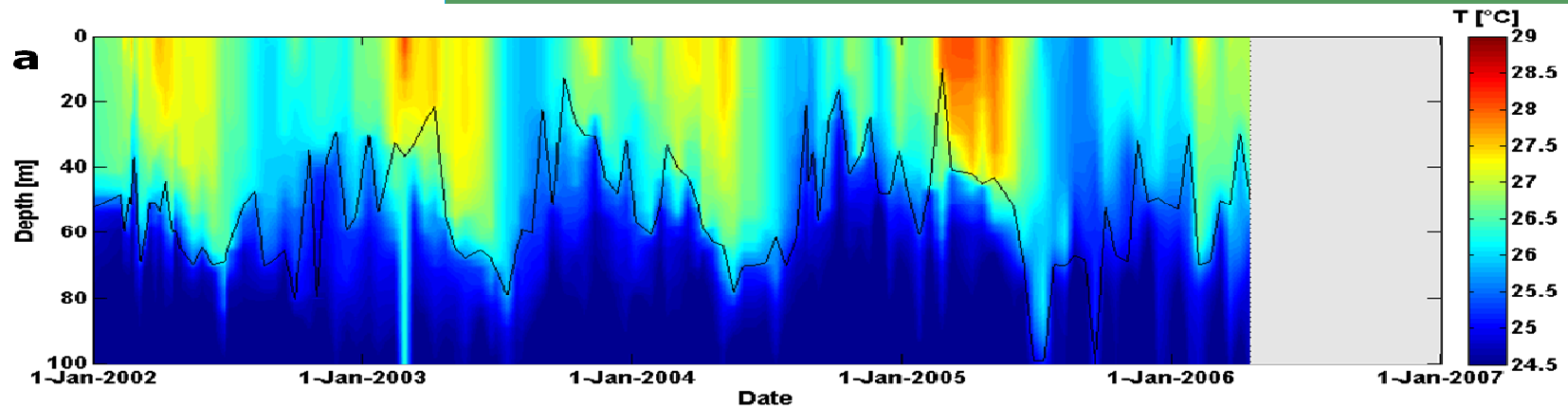
EI



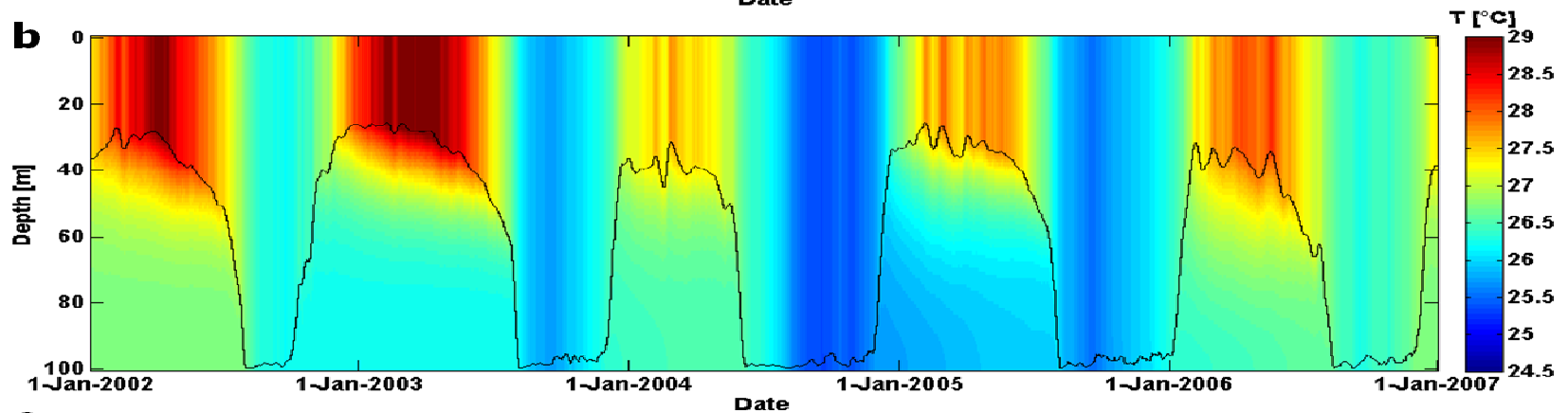


Results: Kigoma

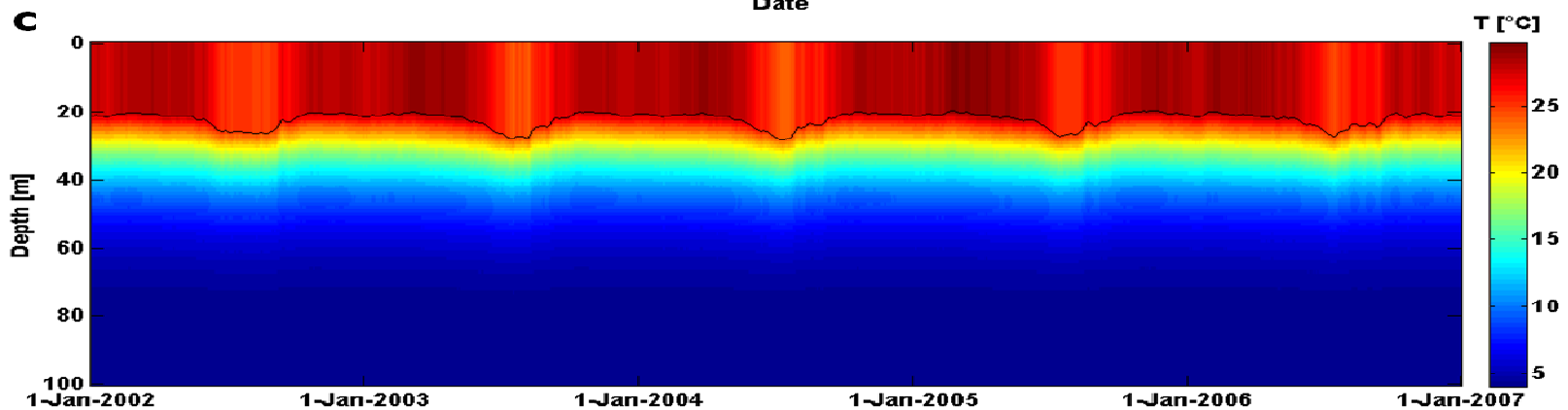
Obs



AWS



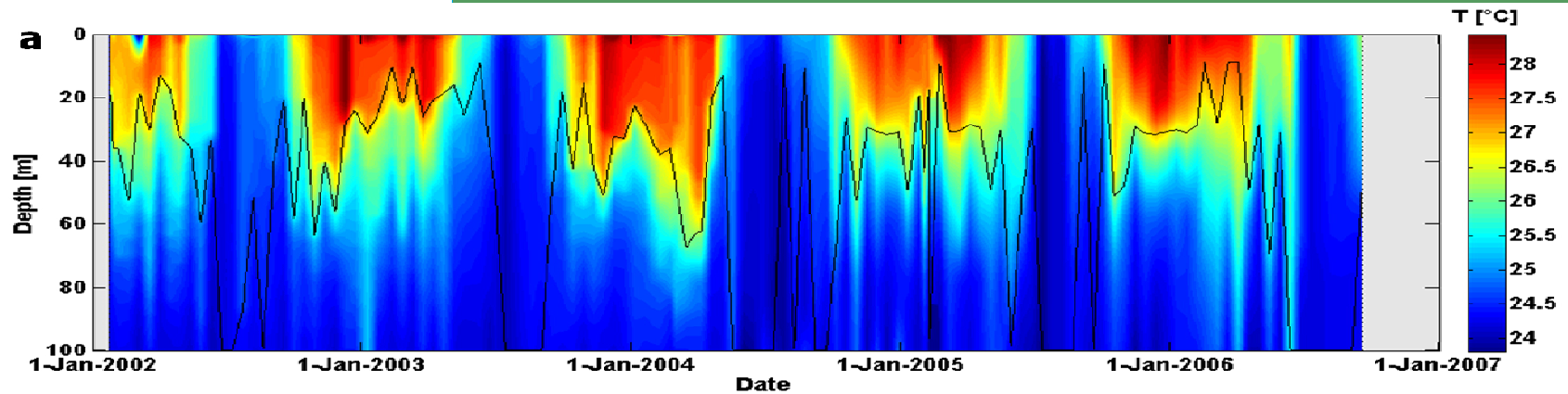
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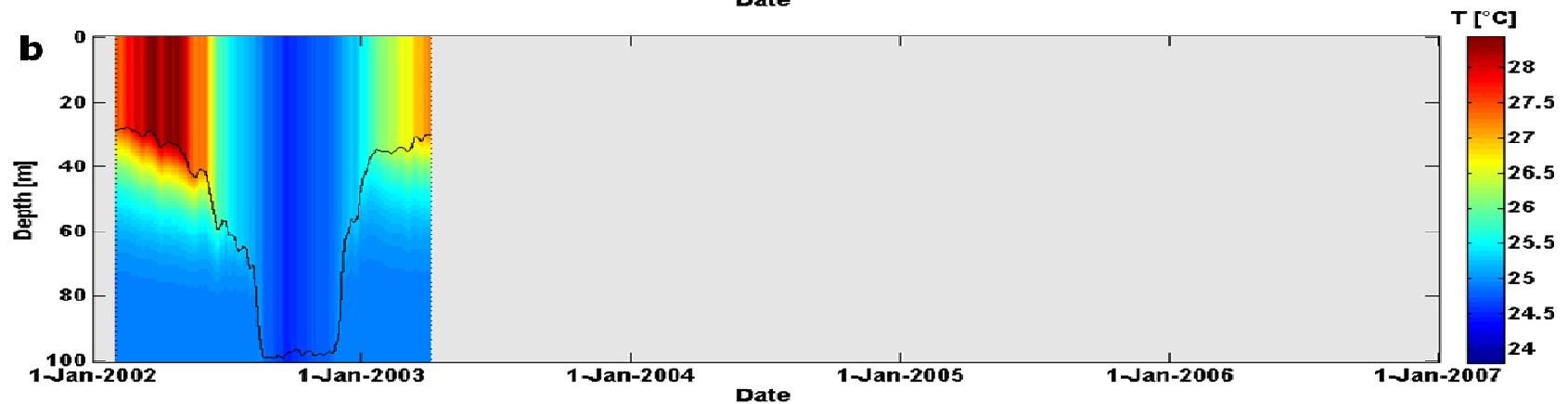


Results: Mpulungu

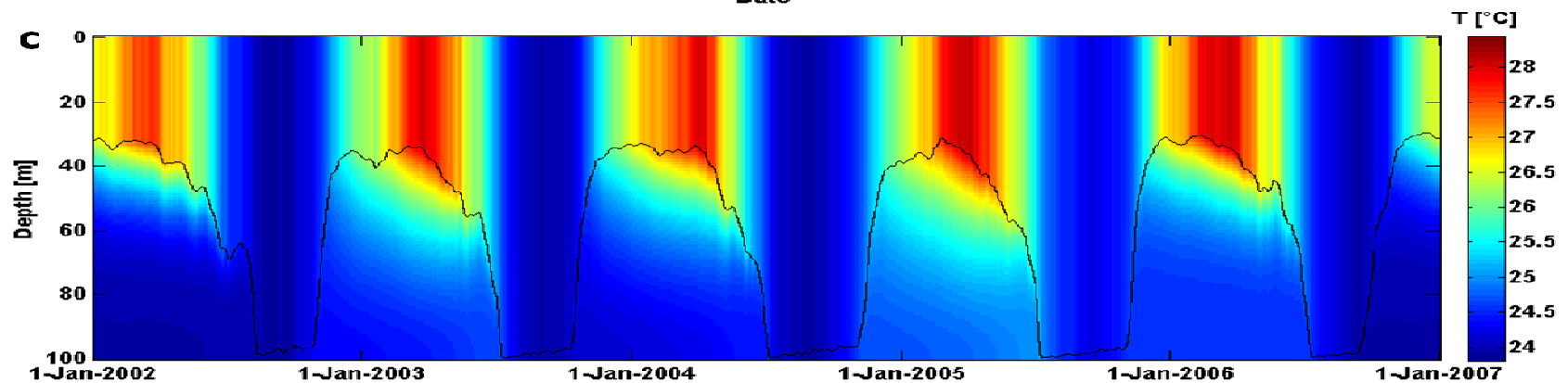
Obs



AWS



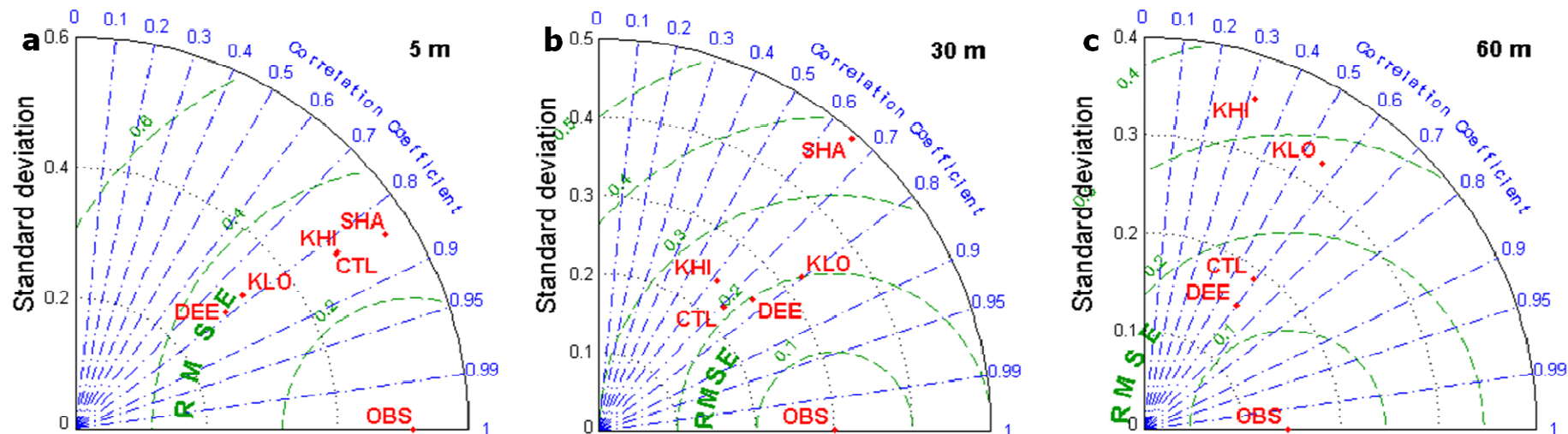
EI





Sensitivity: external parameters

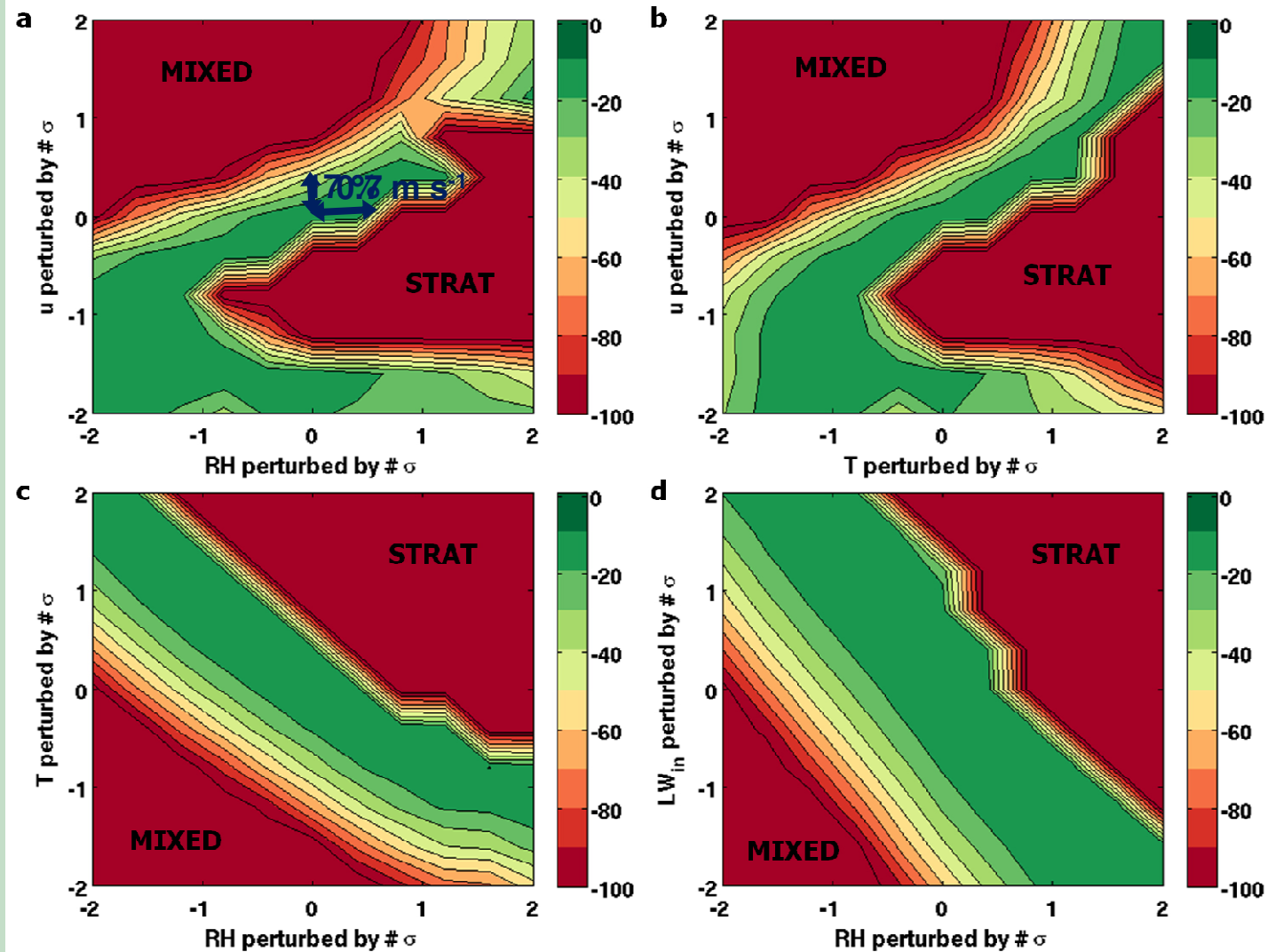
CTL: control
KLO: $k = 0.15 \text{ m}^{-1}$
KHI: $k = 0.46 \text{ m}^{-1}$
SHA: $h_{\text{LAKE}} = 30 \text{ m}$
DEE: $h_{\text{LAKE}} = 120 \text{ m}$



- meromictic lakes: correct mixing regime is only a delicate equilibrium
- need for careful model configuration
- near-surface temperatures are robust, however



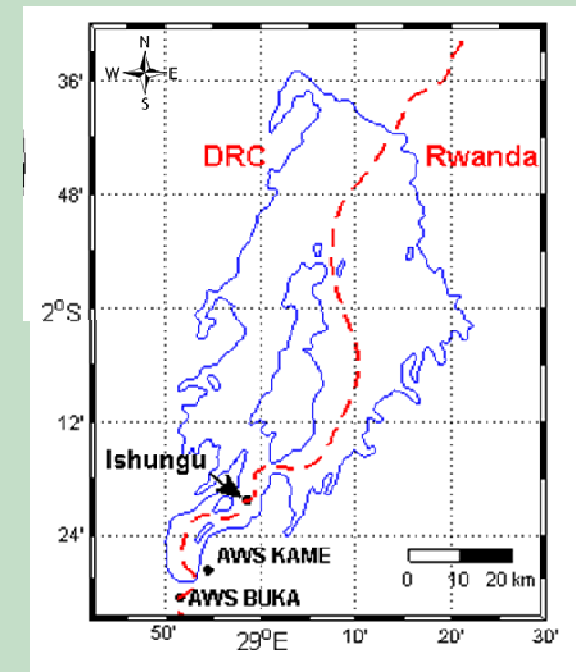
Sensitivity: forcing fields





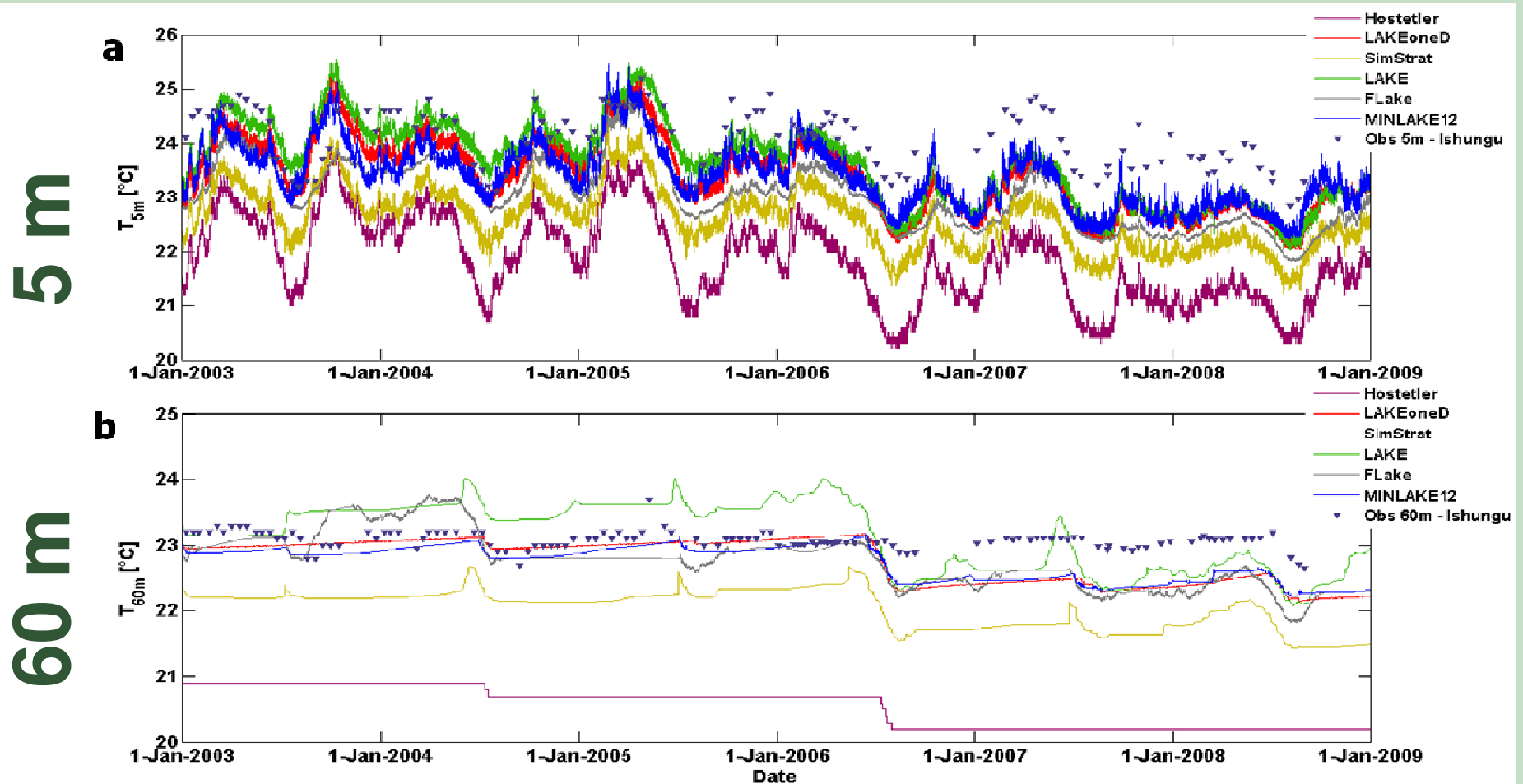
LakeMIP Kivu

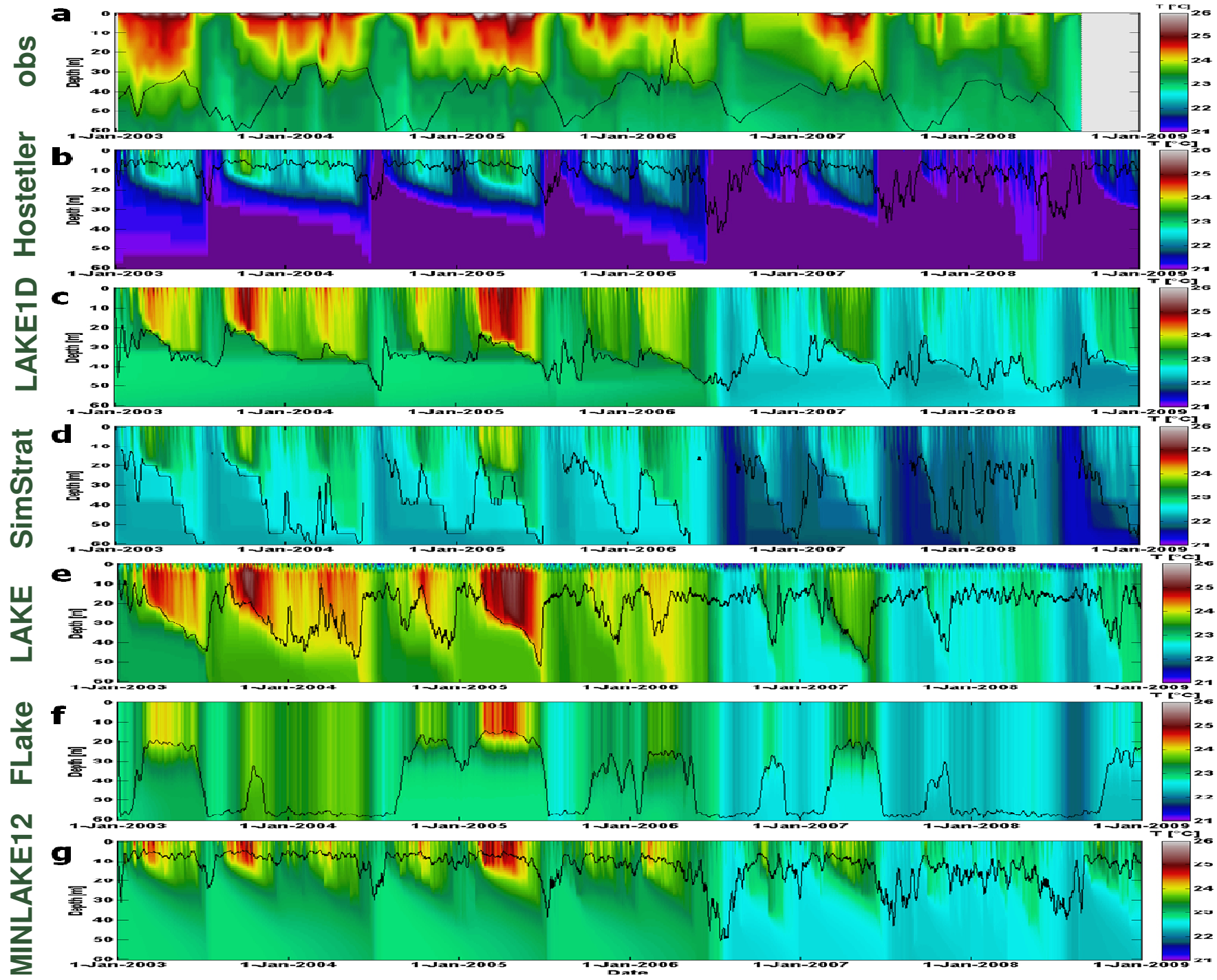
- 8 models confirmed, data of 6:
 - Hostetler, LAKEoneD, SimStrat, LAKE, FLake, MINLAKE2012
 - (DYRESM, CLM4-LISSS)
- Unified protocol:
 - two main simulations:
 - Freshwater 60m
 - Saline simulation 240m including CO₂ and CH₄
 - two forcing AWSs:
 - Bukavu
 - Kamembe
 - 240m: salinity, CO₂ and CH₄ as forcing data
 - 240m: uniform equation of state (Schmidt et al., 2012)
 - 240m: geothermal heat flux = 0.3 W m^{-2} (Schmidt, 2010)
 - 1 year spin up
 - mean lake's k (= 0.27 m^{-1})
 - sensitivity experiments for k , geothermal heat flux, sediment routine, surface flux schemes and wind velocity
 - ...





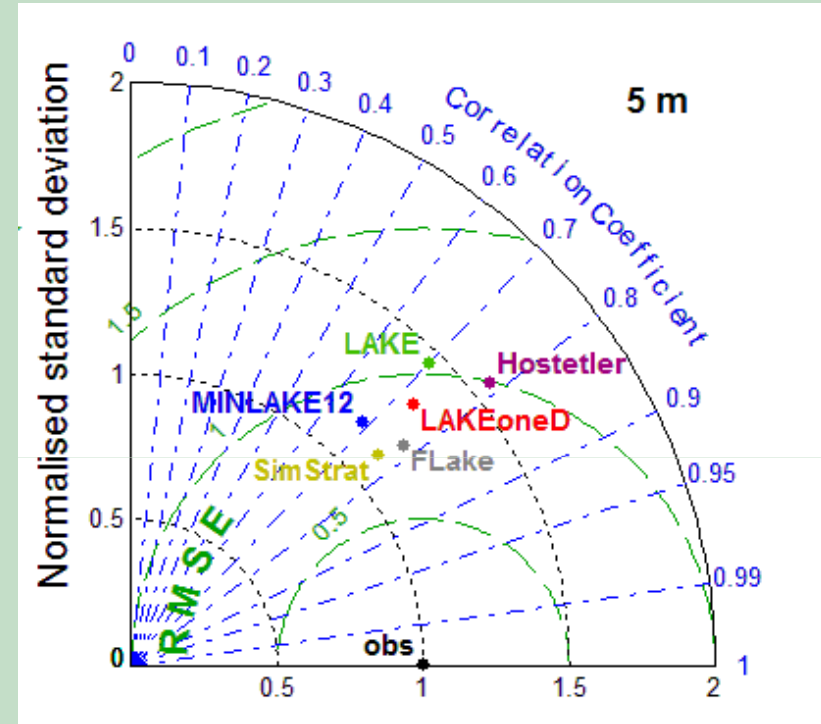
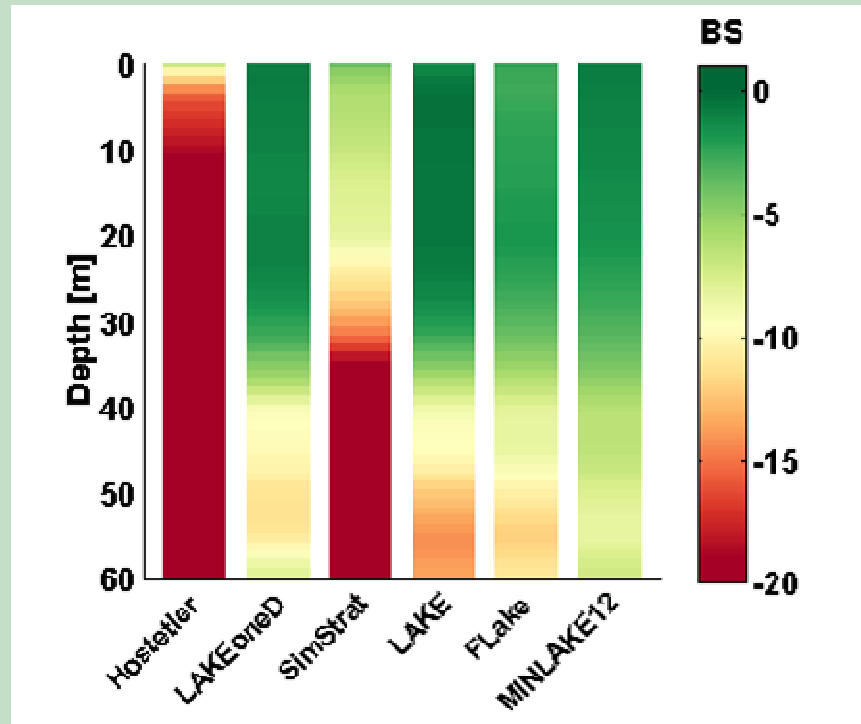
LakeMIP: results







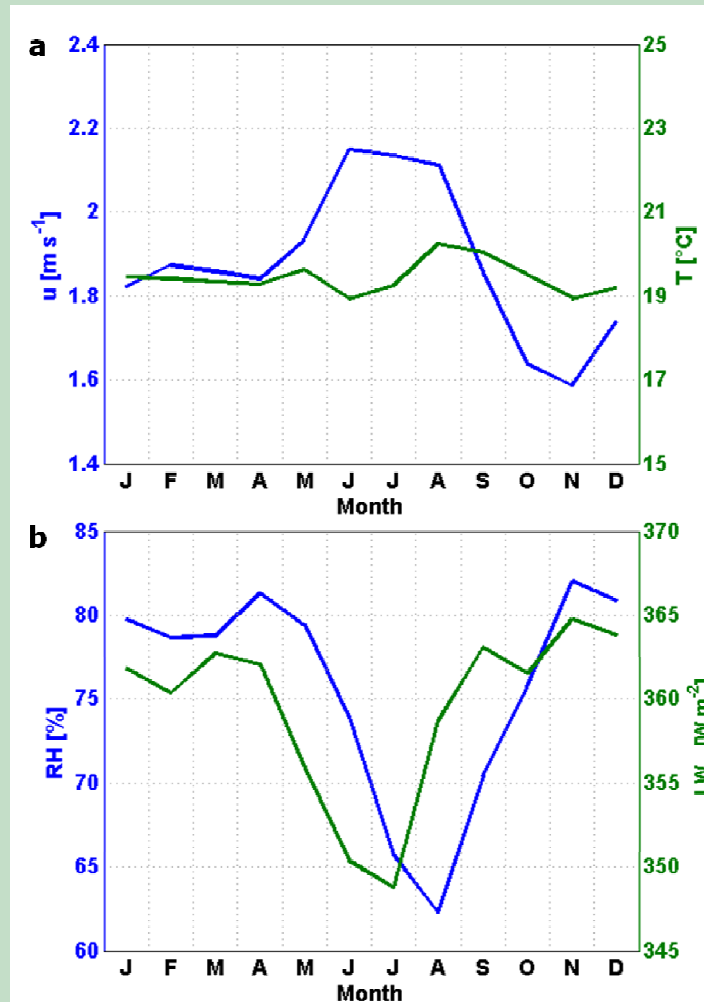
skill scores



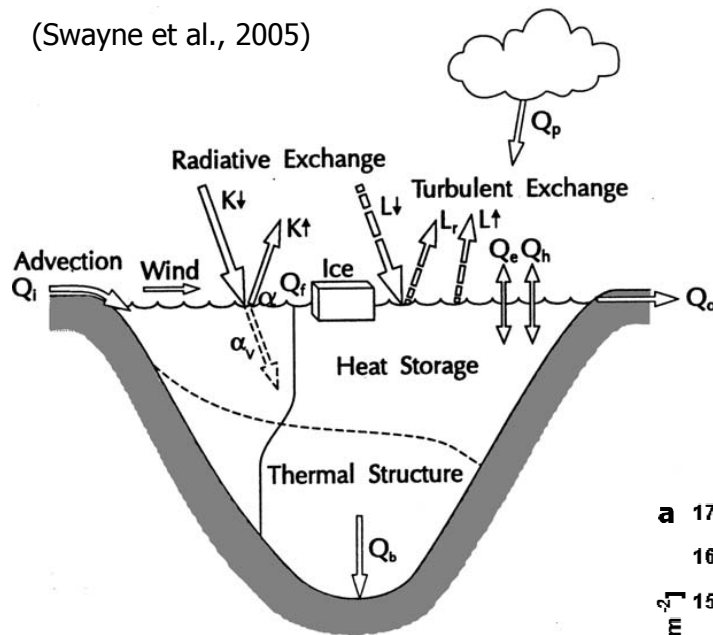
- FLake shows good skill in the control simulation, but very low skill in most sensitivity experiments
- cfr. nonlinear response



Mixing seasonality controls?



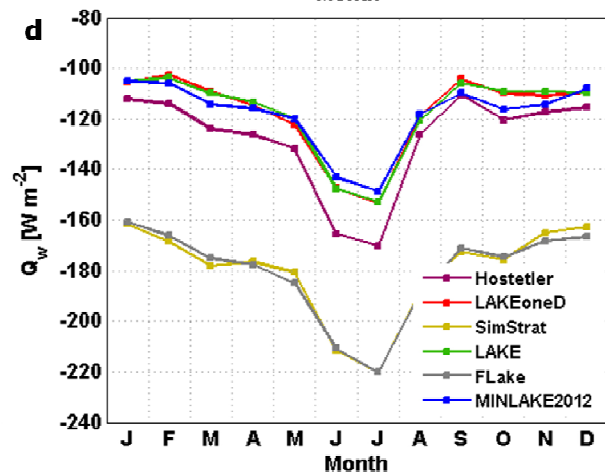
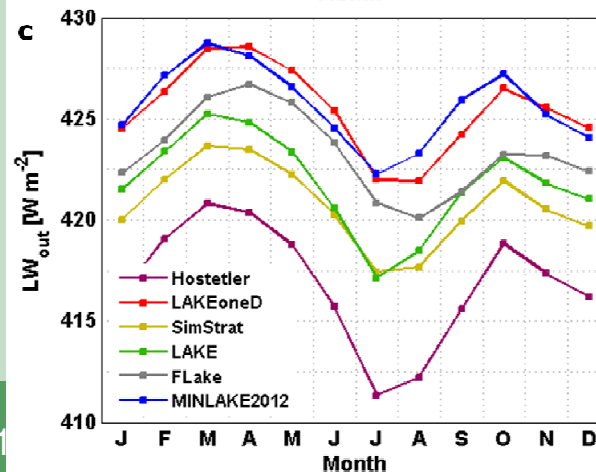
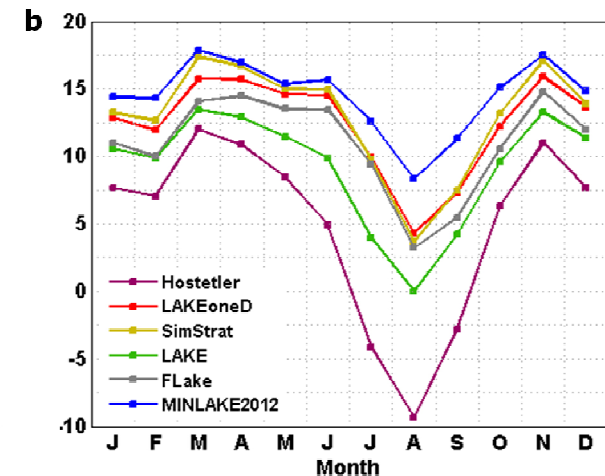
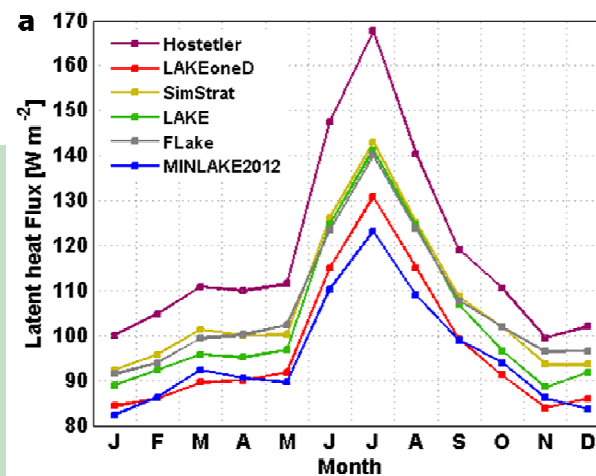
(Swayne et al., 2005)



Surface energy budget

$$SW_{\text{net,VIS}}(z) = SW_{\text{in}}(1-\beta)(1-\alpha_s)e^{-kz}$$

$$SW_{\text{net,NIR}} + LW_{\text{in}}(1-\alpha_L) = LW_{\text{out}} + LHF + SHF + Q_w$$





Conclusions & outlook

- conclusions
 - FLake reproduces lake AGL's thermal structure ...
 - ... when correcting for u (and k)
 - nonlinear response to deficiencies in input data and model configuration leading to regime switches
 - 5 m temperature however much more robust
 - Compared to other models, FLake shows good skill, but only for one default simulation!
 - lake Kivu's mixing regime is regulated by RH and LW_{in} seasonality
- outlook
 - surface energy balance study from AWS (Stijn Bruggen)
 - CCLM-FLake 2001-2012: Era-interim + evaluation
 - CCLM-FLake 2071-2100: CORDEX ($\sim 0.0625^\circ$) + CC attribution

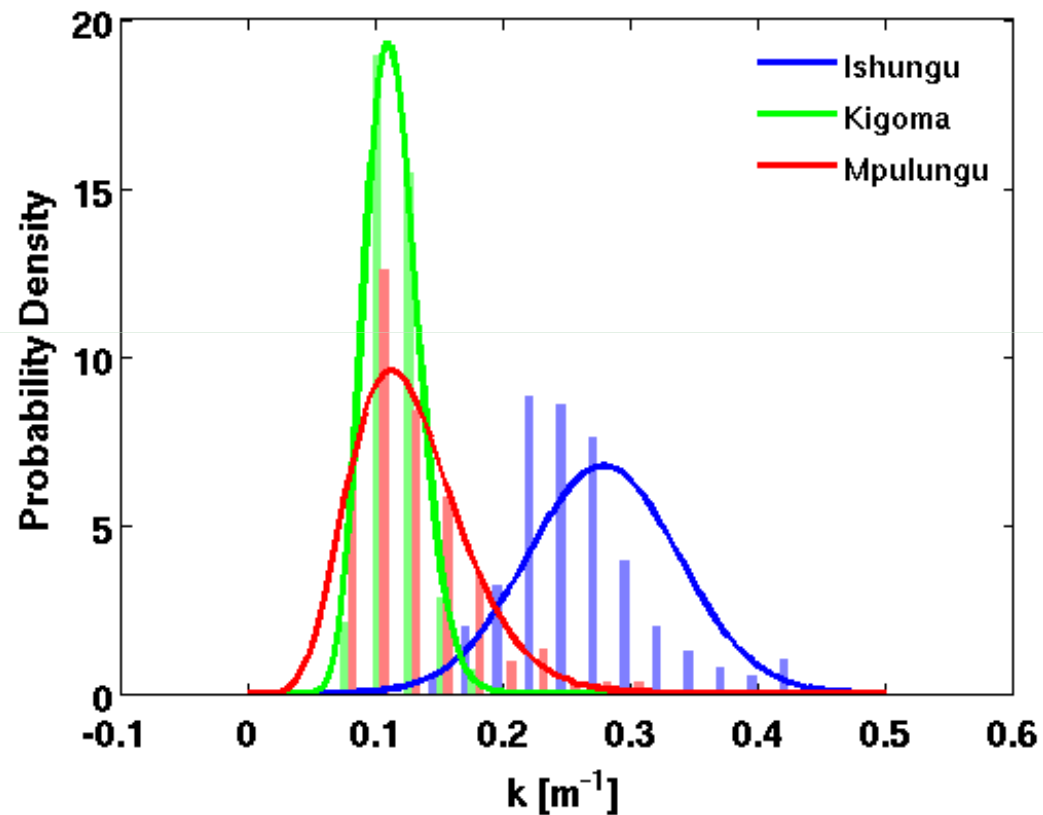
Thank you for your attention!

Acknowledgements: FWO, BELSPO

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Method: FLake configuration





Method: FLake configuration

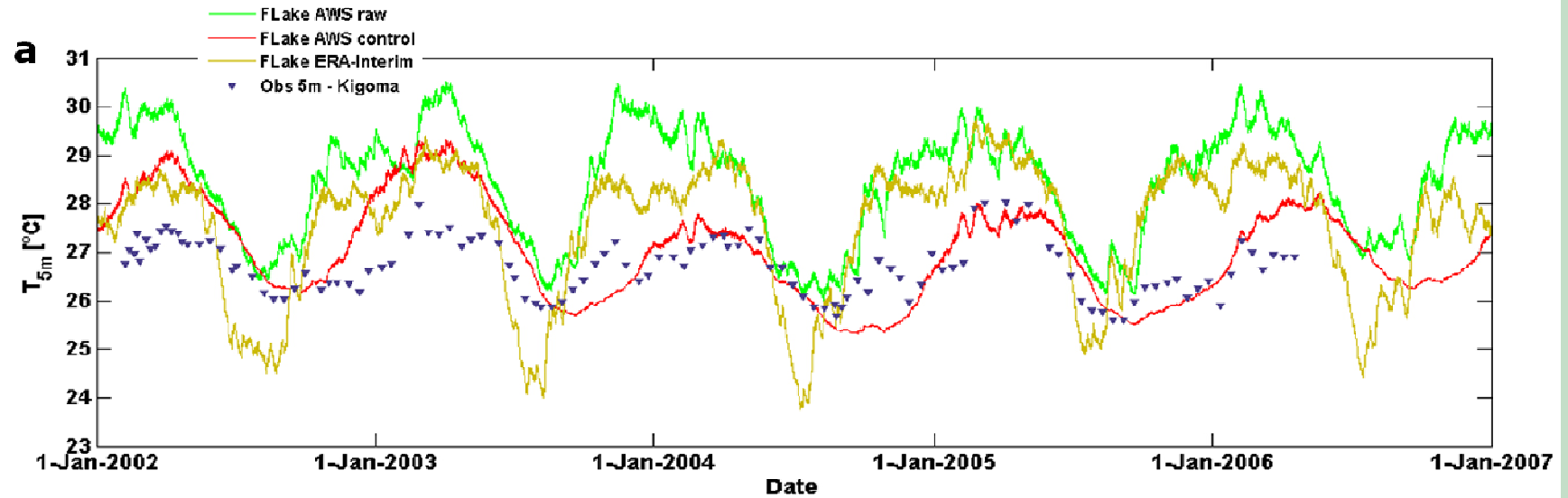
	Ishungu Basin	Kigoma	Mpulungu
General characteristics			
Lake	Kivu	Tanganyika (northern basin)	Tanganyika (southern basin)
Latitude	2° 20' 25'' S	4° 51' 16'' S	8° 43' 59'' S
Longitude	28° 58' 36'' E	29° 35' 32'' E	31° 2' 26'' E
Altitude (m a.s.l.)	1463	768	768
Depth (m)	120	600	120
Number of CTD casts	174	119	126
Water transparency			
Number of secchi depths	163	114	124
Average k (m ⁻¹)	0.28	0.11	0.13
σ_k (m ⁻¹)	0.06	0.02	0.05
Minimum k (m ⁻¹)	0.15	0.07	0.06
Maximum k (m ⁻¹)	0.46	0.17	0.31
Vertically averaged scores for control run			
σ_T (°C)	0.30	0.70	0.67
(relative to $\sigma_{T,obs}$ (°C))	0.32	0.49	0.65)
RMSE _c (°C)	0.22	0.59	0.89
r	0.71	0.51	0.05
BS	-0.13	-9.63	-1.81

	AWS1	AWS2	AWS3
Location			
Corresponding evaluation site	Ishungu	Kigoma	Mpulungu
Latitude	2° 30' 27'' S	4° 53' 15'' S	8° 45' 59''
Longitude	28° 51' 27'' E	29° 37' 11'' E	31° 6' 25''
Altitude (m a.s.l.)	1570	777	782
Setup of this study, after corrections			
Start of observation	1 Jan. 2003	1 Jan. 2002	2 Feb. 2002
End of observation	31 Dec. 2011	31 Dec. 2006	4 Apr. 2003
Meteorological averages			
T (°C)	19.4	24.5	24.1
RH (%)	76	70	58
u (m s ⁻¹)	1.9	0.3	2.6

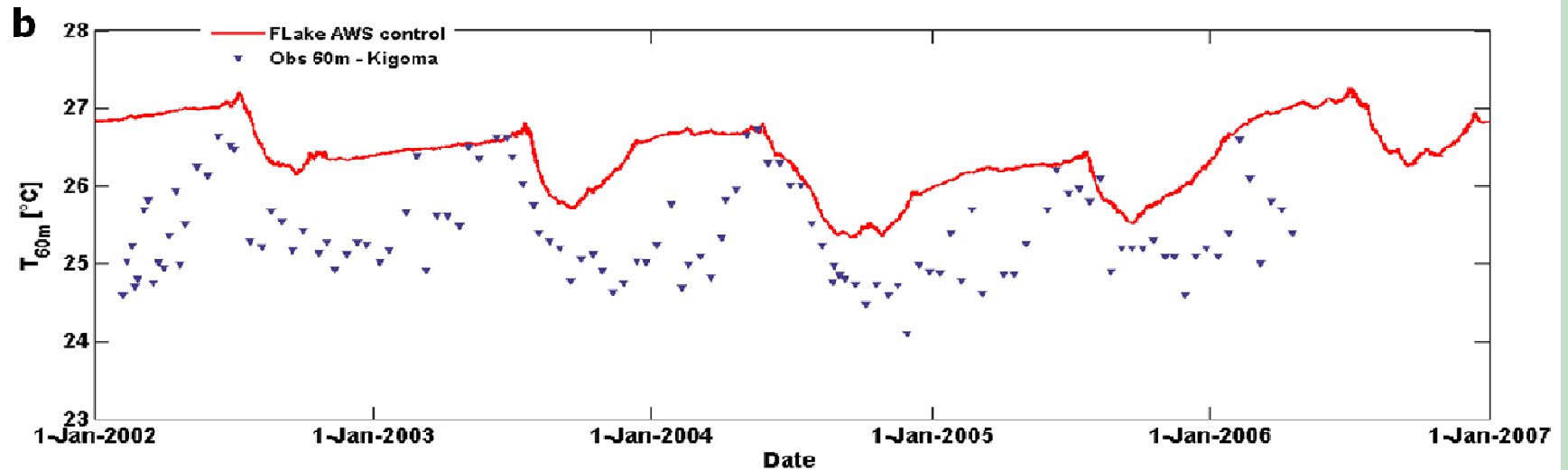


Results: Kigoma

5 m

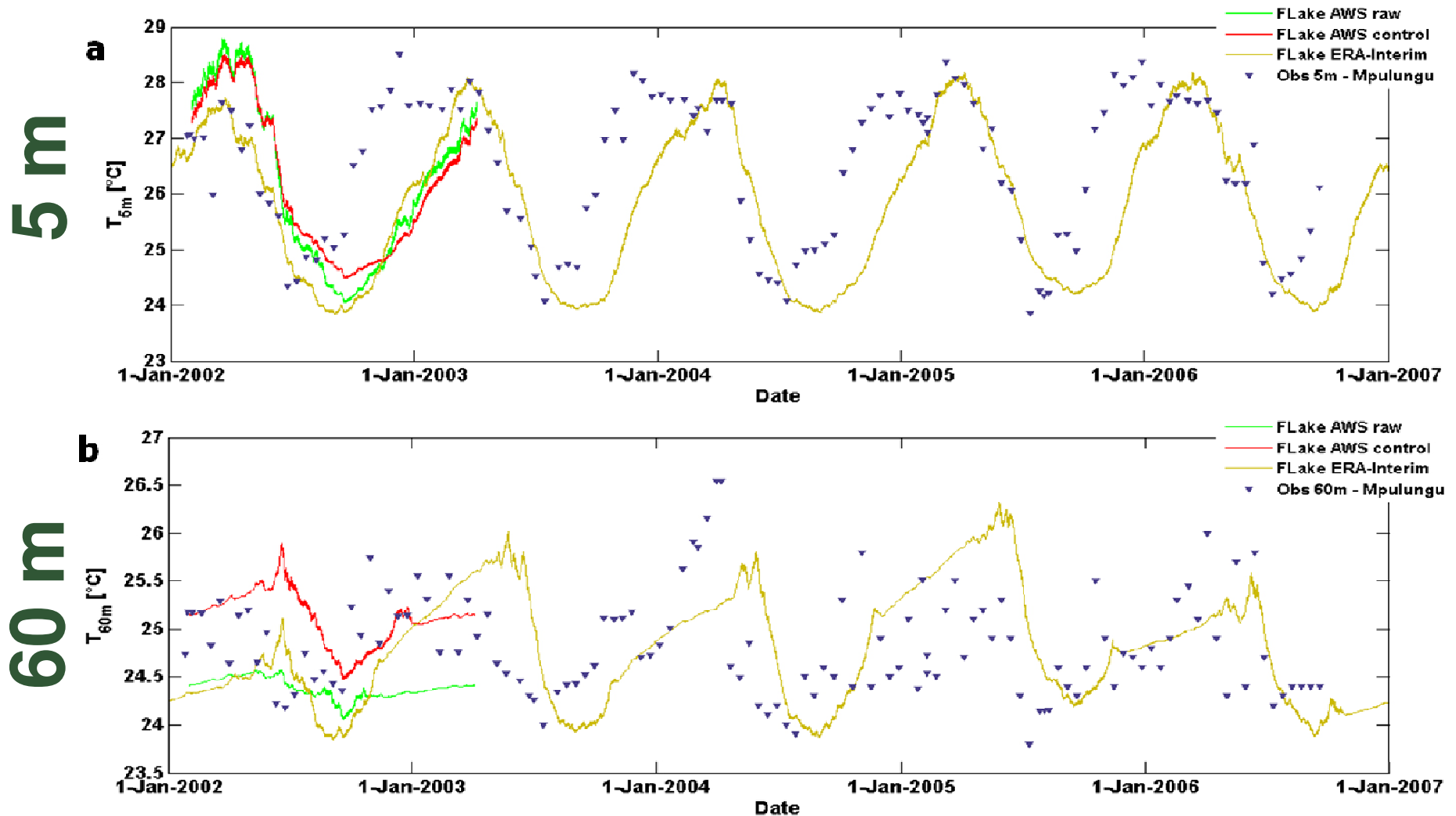


60 m





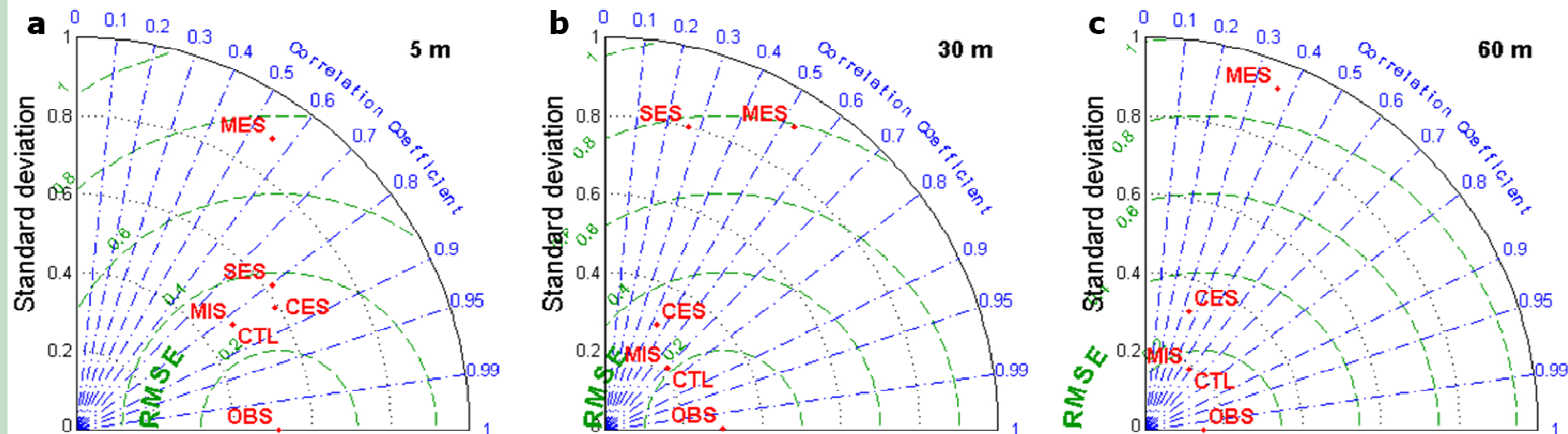
Results: Mpulungu





Sensitivity: initialisation

CTL: control
CES: control excl spin-up
MIS: mixed incl spin-up
MES: mixed excl spin-up
SES: stratified excl spin-up



- preferred initialisation: climatology including spin-up (CTL)
mixed including spin-up (MIS)
stratified excluding spin-up (SES)

↪ If no data available
↪ If spin-up not possible